Returns of Chinook Salmon in Relation to Juvenile Size at Release

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ERRATA

PAGE 6

(a) Total catch

Para. 1, line 1, should read:

An estimated 2,401 fish from all release groups (years combined) ...

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ABSTRACT

Bilton, H. T. 1983. Returns of chinook salmon in relation to juvenile size at release. Can. Tech. Rep. Fish. Aquat. Sci. 1245: iv + 33 p.

An experiment was conducted to determine the effect of size at release of juvenile chinook salmon on their subsequent survival, age at maturity, and growth. Larger juvenile sizes at release were achieved for the same length of rearing period by accelerating growth of fish in water at elevated temperatures. Three releases of marked and nose - tagged accelerated chinook salmon juvenile were made from the Big Qualicum hatchery site, Vancouver Island, June 12, 1976; April 20-26, 1977; and June 2-5, 1978. In the fall of each year from 1977 to 1982 a total of 311 marked adults were recovered at the Big Qualicum River. In addition, 2,401 fish were estimated to have been caught by the fishery during 1977 to 1982. Analysis of these returns indicated that size at release had a significant affect on the percentage that returned. A line of regression describing the relationship between release size and percent return indicated a strong positive, curvilinear relationship between the two factors ($r^2 = 0.88$, $y = -1.31 + 0.11x + 0.07x^2$). For example, the curve indicates a 1.9% return from 6 g juveniles and a 9.6% return from 12 g juveniles, a 5-fold increase in the return rate.

The mean age of fish in the escapement (3.13 years) was significantly higher than that for fish in the catch (2.70 years). Among 2-year-olds in the escapement, there was a significant positive correlation between average juvenile release weight and the percent of 2-year-olds in the escapement.

On the average, the fishery caught 88% of the fish that returned from the three releases. There was evidence of selection by the fishery for younger aged fish. Younger fish, particularly 2-year-olds, contributed most heavily to the Georgia Strait sport fishery. Between 60 and 82% of all fish caught were taken by the Georgia Strait troll and sport fisheries. The sport fishery alone, caught between 44 and 64% of all fish caught.

RÉSUMÉ

Bilton, H. T. 1983. Returns of chinook salmon in relation to juvenile size at release. Can. Tech. Rep. Fish. Aquat. Sci. 1245: iv + 33 p.

L'expérience visait à déterminer l'incidence de la taille de saumons quinnats juvéniles, au moment de leur libération, sur leur survie ultérieure, leur âge à maturité et leur croissance. Pour obtenir des saumons juvéniles de plus grand taille, au moment de leur libération, et avec une période d'engraissement de même durée, il a fallu accélérer la croissance des poissons dans des eaux à température élevée. Le 12 juin 1976, entre le 20 et le 26 avril 1977 et entre le 2 et le 5 juin 1978, trois groupes de saumons quinnats juvéniles à croissance accélérée marqués et étiquetés sur le nez ont été relâchés de la pisciculture de Big Qualicum sur l'île Vancouver. Durant les automnes 1977 à 1982, on a repris au total 311 adultes marqués dans la rivière Big Qualicum. On estima en outre que les pêcheurs avaient pris pendant la même période 2 401 poissons. L'analyse des captures montra que la taille des poissons au moment de leur libération avait une incidence majeure sur le pourcentage de ceux qui revenaient à leur lieu de départ. Une courbe de régression décrivant la relation entre la taille des poissons au moment de leur libération et le pourcentage de ceux revenant à leur point de départ révéla un rapport curvilinéaire élevé et positif entre les deux facteurs (r^2 = 0,88, y = -1,31 + 0,11 + 0,07x2). La courbe révèle, par exemple, que 1,9% des saumons juvéniles de six grammes étaient revenus à leur point de départ, contre 9,6% pour ceux de douze grammes, c'est-à-dire un taux cinq fois supérieur.

L'âge moyen des poissons qui avaient échappé aux pêcheurs (3,13 ans) était notamment plus élevé que ceux qui avaient été pris (2,70 ans). Il y avait une corrélation positive importante entre le poids moyen des saumons juvéniles au moment de leur libération et le pourcentage de poissons de deux ans qui avaient échappé aux pêcheurs.

Les pêcheurs prirent en moyenne 88% des poissons des trois groupes libérés, que revinrent à leur point de départ. Les pêcheurs capturèrent de toute évidence les poissons les plus jeunes. Les pêcheurs sportifs du détroit de Georgie, pour leur part, capturèrent surtout des poissons plus jeunes, de deux ans principalement. Les pêcheurs commerciaux et sportifs du détroit capturèrent de fait de 60 à 82% de tous les poissons. De 44 à 64% des prises étaient attribuables aux seuls pêcheurs sportifs.

INTRODUCTION

Under normal British Columbia salmon hatchery operations, juvenile chinook salmon (Oncorhynchus tshawytscha) are reared at ambient water temperatures for approximately 90 days, before being released to the sea as approximately 6 g juveniles. To increase production (the biomass of fish to the fishery per smolt released), hatchery management techniques require examination and evaluation. One of these pertains to the best combination of time and size at release of juveniles in order to maximize the yield. There is evidence from United States hatcheries that survival of juvenile chinook salmon can generally be improved by increasing the size of juveniles at release (Wallis 1968). There is little evidence of this kind for most Canadian hatcheries.

The objective of this study is to determine the effects of size at release of juvenile chinook salmon on their subsequent survival, age at maturity, and growth. Larger juvenile sizes at release could be achieved by accelerating growth of the fish in water at elevated temperatures for the normal period of rearing time. Such a technique would have the advantage of increased survival resulting in a greater yield of fish to the fishery.

In the winter of 1976, 1977 and 1978, experiments to accelerate growth of chinook juveniles were initiated in an experimental facility at the Big Qualicum hatchery site on Vancouver Island. In the spring of each year the resulting juveniles were tagged and released. This report deals with the effects of size at release of juvenile chinook salmon on their subsequent survival, age at maturity and growth. Contributions of the various experimental groups to both the catch and the escapement are considered.

MATERIALS AND METHODS

LOCATION

The experiment was carried out in an experimental heated-water rearing facility on the Big Qualicum River hatchery site, Vancouver Island, B.C. The Big Qualicum River is located on the east coast of Vancouver Island and flows into Georgia Strait, approximately 50 km north of Nanaimo.

DONOR STOCK AND REARING

Chinook eggs from the Big Qualicum River were used in each of the three years:

1976 release - 94,662 eggs were collected on two dates, on November 3 and 5, 1975. The eggs were fertilized and transferred to Heath-type trays for incubation at ambient water temperatures. By February 15, 1976 all eggs had hatched. Resultant fry (89,176) were ponded into large outdoor circular tanks on April 12, 1976. On May 3, 1976, 42,864 fry were transferred into the experimental hatchery and divided equally among 11 circular fiberglass tanks, 1.83 m in diameter by 1.22 m deep. All incoming water was forced through two Baker sand-filters and four Nature-gard ultra-violet sterilization units before entering the rearing tanks. Water temperature was maintained at approximately 14°C, with a flow of from 30-37 l/min. Fish were reared under fluorescent lights which were operated automatically by a timer. The daily photoperiod was increased gradually to coincide with that of natural daylight. Fish were fed a diet of Oregon moist pellet (OMP) by automatic Allen-type feeders.

1977 release - 57,049 eggs were collected on October 8, 11, 14, 1976. The eggs were fertilized and transferred to Heath-type trays for incubation at an elevated temperature of 10°C. All eggs hatched between November 24 and December 7, 1976. Over the period January 6 to January 21, 1977, 54,817 fry were ponded into large outdoor tanks at an average ambient water temperature of 6°C. On January 28, 1977, 47,547 of these fry were transferred into 11 tanks in the experimental hatchery. Water temperature was maintained at an average of 10.4°C throughout the period of rearing. Other conditions for rearing were similar to those for the 1976 release.

1978 release - 55,789 eggs were collected on October 4, 1977. The eggs were fertilized and transferred to Heath-type trays for incubation at ambient water temperatures in the "eyeing" station. On November 24, 1977, 51,514 "eyed" eggs were transferred into the experimental hatchery. Of these, 26,514 were divided among 7 Heath-type trays. The remaining 25,000 "eyed" eggs were planted into gravel in a gravel-box. Eggs of both groups were incubated through to hatching at an average ambient temperature of 7.5°C. Over the period February 24 to March 9, 1978, 44,766 fry were ponded into the 11 tanks in the experimental hatchery. Water temperature was maintained at an average of 11.6°C throughout the period of rearing. Other conditions for rearing were similar to those for the 1976-77 releases.

MARKING, GRADING, TAGGING, AND RELEASE

1976 release - Between June 8-11, 1976, accelerated chinook juveniles were marked by removal of the adipose fin and tagged using binary-coded wire-nose-tags. Fish were first anesthetized, marked, and

graded[1] into size categories, small, medium and large, based on their fork length. Fish were then tagged and transferred to a release pond.

On June 12, 1976, 35,194 tagged juveniles were released into the Big Qualicum River.

1977 release - Between April 11-19, 1977, juveniles were marked and nose-tagged. The procedure was the same as that for the 1976 release with the exception of grading to size categories. In 1977 the grading of fish into three size categories had to be discontinued part way through tagging because the extra handling was causing a significantly high mortality among the tagged juveniles immediately after tagging. As a result, although a number of tag codes were used, they did not refer to any particular size group. Prior to release, samples were removed for subsequent seawater challenge tests (Clarke and Blackburn 1978).

Over the period April 20-26, 1977, 36,067 tagged juveniles were released into the Big Qualicum River.

1978 release - Between April 11-15, 1978, accelerated chinook juveniles were marked and nose-tagged. The procedure was the same as that for the 1976 release. The two groups of fish that originated from the tray and gravel incubation systems were each graded into three size categories, small, medium, and large on the basis of their fork length (the same criteria for arbitrarily determining size categories used in the 1976 release were used in the 1978 release). Fish were then tagged and transferred to a Burrows pond for release. Prior to release, samples were removed for subsequent seawater challenge tests (Clarke and Blackburn 1978).

Over the period June 2-5, 1978, 32,180 tagged juveniles were released into the Big Qualicum River.

RECOVERY OF ADULTS

Escapement - Marked (those with a missing adipose fin) adult chinook salmon were recovered at the weir on the Big Qualicum River in the fall of each year from 1977 to 1982. All marked adults were killed and sampled for weight (kg) and sex. The heads were removed, frozen and retained for subsequent examinations for nose-tags. The number of fish from each of the release groups of juveniles was determined. For each group of tagged juveniles released, the percent that returned as tagged adults was

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[1]Size categories were determined for fish on the basis of a sample of 559 fish that were removed, anesthetized, measured for fork length and returned to the population. A length frequency curve was derived from these data which was used to determine the limits of the three size categories. Arbitrarily, it was decided on the basis of this curve that the first 25% of the fish on the left hand side of the curve would be classified as small, the 50% in the middle of the curve as medium, and the 25% on the extreme right hand side of the curve as large.

calculated. The average weights of male and female adults by age[1] at return were also calculated.

Fishery - Nose-tagged chinook were recovered in the commercial fisheries (net and troll) by random sampling of fishery catches with a target intensity of 20% (Heizer, Cook and Argue 1978). Estimates of numbers caught of each tag group were obtained from the actual number of tag recoveries, and the sampling effort in the various catches.

Tagged chinooks from sport catches were recovered in the coast-wide mark and recovery program (Argue, Coursley and Harris 1977). This program depends on voluntary return of heads from marked chinook and coho salmon by fishermen. An "awareness factor" of 0.15 was used to estimate the total number of tagged accelerated chinooks that contributed to the sport fishery. This factor is based on results of a Georgia Strait creel census, and in all fishing areas it was assumed that 15% of marked fish caught were recognized and reported.

STATISTICAL ANALYSIS

For each group of tagged juveniles released, the calculated values for the percent that returned as adults, and their average sizes, were used to calculate various correlation coefficient (Pearson r) and regression statistics.

RESULTS

RETURNS

(a) Numbers from three releases

A total of 452 chinooks from the 1976 release, 86 from the 1977 release, and 2,174 from the 1978 release were recovered in the escapement and the catch (Table 1-3). The percent return of chinooks (catch plus escapement) was lowest from juveniles released on April 20-26, 1977 (0.24%). The return from the June 12, 1976 release was 1.28%, more than five times that of the 1977 release. The highest return resulted from the June 2-5, 1978 release (6.75%) which was approximately five times that of the 1976 release. Returns

[1]Age represents the period elapsed between the brood year and the year of recovery.

from gravel and tray incubated eggs whose progeny made up the 1978 release, returned at similar rates (a 0.5% difference, which may have been related mostly to mean size of juveniles at release, and not to the method of incubation).

(b) Juvenile size and return

Among fish from the 1976 and 1978 releases, respectively, there was a strong positive relationship between average weight of juveniles at release, the total percent (2's, 3's, 4's, and 5's combined) that returned to the catch plus the escapement (Fig. 1, Tables 1 and 3). Nothing can be said about fish from the 1977 release as only one group was released. When the returns from all groups released over the three years are combined (Fig. 1), a strong positive curvilinear relationship between juvenile release size and percent return was indicated (r^2=0.88. $y=-1.31 + 0.11x + 0.07x^2$). For example, the relationship indicates a 1.9% return from 6g juveniles and a 9.6% return from 12g juveniles, a 5-fold increase in the return rate over that from 6g juveniles.

It was not possible to test for the influence of time of release on returns. However, there was some suggestion of a time effect as evidenced by the poor return of approximately 7g juveniles (Fig. 1) released in April of 1977. When the 1977 data are omitted from the regression calculation, the relationship between juvenile size and percent return is even stronger (r^2=0.93). This group had poor seawater adaptability as evidenced by a 24 h seawater challenge test (Clarke and Blackburn 1978). In contrast, samples of fish from the 1978 release showed good seawater adaptability when subjected to seawater challenge tests on May 16 and June 5.

There were also strong positive relationships between juveniles size at release and the percent that were recovered (catch plus escapement) at each age (Figs. 2, 3, and 4), (percent return of 2's, r^2=0.96; 3's r=0.84, p .01; 4's, r^2=0.91).

Strong positive relationships were indicated between the percent of juveniles that were recovered (catch plus escapement) as 2's in year n and as 3's in year n + 1 (R^2=0.86, $y=-0.31 + 2.09x - 0.27x^2$), and as 3's in year n and as 4's in year n + 1 (r=0.85, p .02, y=0.03 + 0.25x), (Figs. 5 and 6).

(c) Juvenile size and adult size

Average size of adults originating from juveniles of different size in each of the different release groups were determined for fish obtained in the escapement (Table 4). Only the 1978 release provided sufficient numbers of 2-year-old fish to calculate average weight. Two-year-old fish from this release averaged approximately 2 kg in weight (Table 4). Three-year-olds (males plus females) averaged from 5.23 kg (gravel, 1978 release) to 6.59 kg (1977 release) in weight. The average weight of 4-year-old fish ranged between 9.09 kg (gravel, 1978 release) and 9.59 kg (1976 release). Among the 2's there was a weak positive curvilinear relationship between average juvenile release weight and average weight of the age 0.1 fish (r^2=0.55,

$y=2.75 - 0.17x + 0.01x^2$). Among 2-year-old males there was virtually no influence of juvenile weight on adult size ($r^2=0.14$). Among the 3-year-old females there was a quite strong negative curvilinear relationship ($r^2=0.72$, $y=15.11 - 1.87x + 0.10x^2$).

(d) Age composition

In all release groups (years combined) the mean age of a fish in the escapement was 3.13 years (Tables 5-7). The mean age of 2.70 years in the catch was statistically significantly lower ($t=2.79$, d.f.8, $p<.01$) suggesting selection for fish at a younger age by the fishery. Age of fish in both the catch and the escapement ranged between 2- and 5-year-old. Among the 2's in the escapement, there was a significant positive correlation between average juvenile release weight and the percent of 2's in the escapement ($r=0.72$, d.f.=8, $p<.02$). There was also a strong curvilinear relationship between mean juvenile release weight and the mean age of all adults in the escapement ($r^2=0.86$).

(e) Sex ratio

As was expected, all 2-year-old fish that returned were males (Table 8). Most of the 3-year-old fish that returned from the 1976 and 1978 releases were males. Four-year-old fish, on the other hand, were predominantly females. The two 5-year-old fish from the 1976 release were both females.

DISTRIBUTION IN THE CATCH

(a) Total catch

An estimated 2,401 fish from all release groups (years ambient) were recovered in the catches (Tables 1-3), representing 88.5% of 2,712, the total number of fish that returned. Juveniles released April 1977, resulted in the lowest catch contribution (73 fish or 0.20% of the juveniles released). Juveniles released June 1976 contributed to the fishery a total of 409 fish, which was more than 5 times the contribution from the April 1977 release. The highest catch was realized from the June 1978 release (1,919 fish or 5.96% of the juveniles released).

There was no obvious difference in the proportion of the total return caught by the fishery among the small, medium, and large size categories of juvenile (Tables 1-3). The catches were composed mostly of 2- and 3-year-old fish (both ages combined made up from 73 to 96% of the catches, Tables 5-7).

(b) Distribution

Between 60% (1976 release) and 82% (1977 release) of all fish caught were taken by the Georgia Strait troll and sport fisheries (Tables 9-11). The sport fishery alone, caught between 44 and 64% of all fish caught. Of the catch of fish from the 1976 and 1978 releases, 6.9% and 1.1%, respectively, were caught in the Alaska commercial fishery. None from the 1977 release were caught in this fishery. Only fish from the 1978 release were caught in the Washington and Oregon net and sport fisheries.

Among catches of fish from the different release groups (years combined) there was a highly significant linear negative correlation between age of fish and percent caught in the Georgia Strait fishery ($r=-0.92$, d.f.14, $p<.001$), indicating that fish at a younger age (particularly 2-year-old fish) contributed more heavily to the sport fishery than did the older ones (Tables 9-11). For catches of fish from all release groups, there was a significant positive correlation between age of fish and percent caught in the Northern and Central troll fisheries ($r=0.57$, d.f.14, $p<.01$, $y=-33.0 + 10.15x$), indicating the older fish contributed more heavily to the fisheries. In all release groups 3-year-old fish contributed most to the Georgia Strait troll catches.

DISCUSSION

The objective of this experiment was to determine the affects of accelerating the growth of chinook juveniles to achieve larger sizes at release, and to determine the effects of increased size on their subsequent survival, age at maturity, and growth. The data clearly shows that size at release has an effect on the total percent return (catch plus escapement). Larger juveniles returned at a higher rate than did smaller juveniles. The curve also indicates that even higher returns may be achieved from release of even larger juveniles. Currently, production hatcheries release juveniles at approximately 6g in early to mid-June. The returns from these releases have averaged at 2-3%. The present experimental data indicates the returns from the hatcheries can be increased significantly if juveniles are released in June at a larger size. For example, if the constraints of a facility (e.g. warmer water temperatures during incubation or rearing) would permit the production of 9g juveniles, the return rate could be increased to approximately 5.2% from the present 2-3%. Little can be said at present about the simultaneous effects of time and size at release. The very low return from the April 1977 release of 6.9g juveniles does, however, suggests that conditions at that time were not optimal for survival. In the case of coho, both size and time of release had a very significant effect on returns (Bilton et al. 1982), indicating an optimum combination of both factors that will maximize returns. Hence, there is likely a combination of size and time of release for chinook juveniles that will yield maximum adult returns that are probably higher than that achieved in the present experiment. This is currently being examined at the Quinsam hatchery (Bilton et al. 1983).

As was observed for coho (Bilton et al. 1982) where larger juveniles yielded a higher proportion of jacks, the present data indicate larger chinook juveniles yield more jacks (precocious males, 2-year-olds). While at the same time larger juveniles also yielded more 3- and 4-year olds.

There was evidence of selection by the fishery for younger aged fish. Hence, the age composition of fish in the catch was not representative of that in the escapement. Younger fish (particularly 2-year-olds) contributed most heavily to the Georgia Strait sport catches.

In conclusion, the results indicate that size of juveniles at release has a very significant influence on the return rate of the progeny. The data indicate a very substantial improvement over the current returns of 2-3% from 6g juveniles can be achieved by release of larger juveniles on about the same time as they are presently released (early to mid-June). The effects of time of release were not examined. Current experiments measuring both the effects of size and time of release will provide a better understanding of the optimum time-size release window that will achieve maximum returns.

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Table 1. Returns of mature and immature chinook in the catch (C) and escapement (E) originating from 1975 brood year accelerated juveniles released from Big Qualicum River on June 12, 1976, by size category of juveniles released (S=small, M=medium, L=large, T=combined).

Tag code	Juveniles: Size group	Juveniles: No. tagged	Juveniles: $\bar{x}$ weight (g)	2's (77) No. C	2's (77) No. E	2's (77) No. C+E	3's (78) No. C	3's (78) No. E	3's (78) No. C+E	4's (79) No. C	4's (79) No. E	4's (79) No. C+E	5's (80) No. C	5's (80) No. E	5's (80) No. C+E	Total C No.	Total C %	Total E No.	Total E %	Total C+E No.	Total C+E %	C / C+E x 100%
8-6-10	S	7,274	3.58	14	0	14	5	0	5	7	2	9	0	0	0	26	0.36	2	0.03	28	0.39	92.9
8-6-11	M	21,153	5.10	90	0	90	114	3	117	43	23	66	0	2	2	247	1.17	28	0.13	275	1.30	89.8
8-6-12	L	6,767	6.59	55	0	55	72	10	82	9	3	12	0	0	0	136	2.01	13	0.19	149	2.20	91.3
	T	35,194	5.20	159	0	159	191	13	204	59	28	87	0	2	2	409	1.16	43	0.12	452	1.28	90.5

Table 2. Returns of mature and immature chinook in the catch (C) and escapement (E) originating from 1976 brood year accelerated juveniles released from Big Qualicum River on April 20-26, 1977.

Tag code	Juveniles: No. tagged	Juveniles: $\bar{x}$ weight (g)	2's (78) C	2's (78) E	2's (78) C+E	3's (79) C	3's (79) E	3's (79) C+E	4's (80) C	4's (80) E	4's (80) C+E	5's (81) C	5's (81) E	5's (81) C+E	Total C No.	Total C %	Total E No.	Total E %	Total C+E No.	Total C+E %	C / C+E x 100%
8-16-16 to 8-16-24	35,067	6.90	35	0	35	30	13	43	7	0	7	0	0	0	73	0.20	13	0.04	86	0.24	84.9

Table 3. Returns of mature and immature chinook in the catch (C) and escapement (E) originating from 1977 brood year accelerated juveniles released from Big Qualicum River on June 3-5, 1978, by size category of juveniles released (S=small, M=medium, L=large, T=combined).

Treatment	Tag code	Size group	Juveniles: No. tagged	Juveniles: x weight (g)	2's (79): C	2's (79): E	2's (79): C+E	3's (80): C	3's (80): E	3's (80): C+E	4's (81): C	4's (81): E	4's (81): C+E	5's (82): C	5's (82): E	5's (82): C+E	Total: No. C	Total: % C	Total: No. E	Total: % E	Total: No. C+E	Total: % C+E	C/(C+E) x 100%
Acc. Trays	8-10-25	S	2,892	8.14	36	5	41	28	6	34	3	3	6	0	0	0	67	2.32	14	0.48	81	2.80	83
	8-10-26	M	7,503	9.94	188	29	217	229	36	265	55	17	70	2	0	2	472	6.29	82	1.09	554	7.38	85
	8-10-22 8-10-27	L	4,998	12.64	228	16	244	143	23	166	62	11	73	0	0	0	433	8.66	50	1.00	483	9.66	90
		T	15,394	9.92	452	50	502	400	65	465	118	31	149	2	0	2	972	6.31	146	0.95	1,118	7.26	87
Acc Gravel	8-10-28	S	3,995	6.68	41	5	46	75	7	82	11	3	14	0	0	0	127	3.18	15	0.37	142	3.55	89
	8-10-29	M	8,539	9.53	200	28	228	211	14	225	42	13	55	45	0	45	498	5.83	55	0.64	553	6.47	90
	8-10-30	L	4,248	10.45	109	13	122	182	18	200	31	8	39	0	0	0	322	7.58	39	0.92	361	8.50	89
		T	16,782	8.72	350	46	396	468	39	507	84	24	108	45	0	45	947	5.64	109	0.65	1,056	6.29	90
Grand Total			32,180	9.30	802	96	898	868	104	972	202	55	257	47	0	47	1,919	5.96	255	0.79	2,174	6.75	88

Table 4. Mean weight (kg) of mature chinook of different ages in the escapement that originated from accelerated smolts released from Big Qualicum River in 1976, 1977, and 1978.

Release date	Tag code	Juveniles: Treatment	Juveniles: Size group	Juveniles: $\bar{x}$ weight (g)	2's ♂	2's ♀	2's ♂+♀	3's ♂	3's ♀	3's ♂+♀	4's ♂	4's ♀	4's ♂+♀	5's ♂	5's ♀	5's ♂+♀
June 12/76	8-6-10	Acc.	S	3.58	-	-	-	-	-	-	-	11.32	-	-	-	-
	8-6-11		M	5.10	-	-	-	5.95	7.73	6.55	11.14	8.68	9.77	-	8.23	-
	8-6-12		L	6.59	-	-	-	5.91	7.23	6.05	-	-	-	-	-	-
			T	5.20	-	-	-	5.91	7.45	6.14	11.14	9.09	9.59	-	8.23	-
Apr 26/77 to	8-16-16 8-16-24		T	6.90	-	-	-	5.32	7.14	6.59	-	-	-	-	-	-
June 2-5/78	8-18-25	Acc. Tray	S	8.14	2.05	-	-	6.45	-	-	-	7.50	-	-	-	-
	8-18-26		M	9.94	2.05	-	-	5.95	5.68	5.82	9.68	9.41	9.45	-	-	-
	8-18-22		L	12.64	2.27	-	-	6.18	6.73	6.32	8.45	9.23	9.05	-	-	-
	8-18-22				2.27	-	-	4.41	3.82	4.27	-	6.82	-	-	-	-
			T	9.92	2.14	-	-	5.95	5.77	5.96	9.18	9.05	9.05	-	-	-
	8-18-28	Acc. gravel	S	6.88	2.09	-	-	5.27	-	-	9.14	6.86	8.36	-	-	-
	8-18-29		M	9.53	2.00	-	-	4.50	5.18	4.64	9.77	8.86	9.00	-	-	-
	8-18-30		L	10.45	2.27	-	-	5.36	6.55	5.68	10.18	9.41	9.50	-	-	-
			T	8.73	2.09	-	-	5.05	6.05	5.23	9.59	8.95	9.09	-	-	-

Table 5. Percent age composition of mature and immature chinook in the catch (C) and escapement (E) that originated from the 1975 brood years accelerated juveniles released from Big Qualicum River on June 12, 1976, by size category of juveniles released (S=small, M=medium, L=large, T=combined).

Tag code	Size group	Juveniles: No. tagged	Juveniles: $\bar{x}$ weight (g)	Recovered	2's (77): No.	2's (77): %	3's (78): No.	3's (78): %	4's (79): No.	4's (79): %	5's (80): No.	5's (80): %	Total: No.	Total: %	$\bar{x}$ Age
8-6-10	S	7,274	3.58	C	14	53.9	5	19.2	7	26.9	0	0.0	26	100.0	2.73
				E	0	0.0	0	0.0	2	100.0	0	0.0	2	100.0	4.00
				C+E	14	50.0	5	17.9	9	32.1	0	0.0	28	100.0	2.82
8-6-11	M	21,153	5.10	C	90	36.5	114	46.1	43	17.4	0	0.0	247	100.0	2.81
				E	0	0.0	3	10.7	23	82.1	2	7.2	28	100.0	3.96
				C+E	90	32.7	117	42.5	66	24.0	2	0.8	275	100.0	2.89
8-6-12	L	6,767	6.59	C	55	40.5	72	52.9	9	6.6	0	0.0	136	100.0	2.66
				E	0	0.0	10	76.9	3	23.1	0	0.0	13	100.0	3.23
				C+E	55	36.9	82	55.0	12	8.1	0	0.0	149	100.0	2.71
	T	35,194	5.20	C	159	38.9	191	46.7	59	14.4	0	0.0	409	100.0	2.76
				E	0	0.0	13	30.2	28	65.1	2	4.7	43	100.0	3.74
				C+E	159	35.2	204	45.1	87	19.3	2	0.4	452	100.0	2.85

Table 6. Percent age composition of mature and immature chinook in the catch (C) and escapement (E) that originated from the 1976 brood year accelerated juveniles released from Big Qualicum River on April 20-26, 1977.

Tag code	Juveniles		Recovered	2's (78)		3's (79)		4's (80)		5's (81)		Total		$\bar{x}$
	No. tagged	$\bar{x}$ weight (g)		No.	%	No.	%	No.	%	No.	%	No.	%	Age
8-16-16	36,067	6.90	C	36	49.3	30	41.4	7	9.6	0	0.0	73	100.0	2.60
to			E	0	0.0	13	100.0	0	0.0	0	0.0	13	100.0	3.00
8-16-24			C+E	36	41.9	43	50.0	7	8.1	0	0.0	86	100.0	2.66

Table 7. Percent age composition of mature and immature chinook in catch (C) and escapement (E) that originated from the 1977 brood year accelerated juveniles released from Big Qualicum River on Jun 2-5, 1978, by size category of juveniles released (S=small, M=medium, L=large, T=combined).

Treatment	Tag code	Juveniles: Size group	Juveniles: No. tagged	Juveniles: $\bar{x}$ weight (g)	Recovered	2's (79): No.	2's (79): %	3's (80): No.	3's (80): %	4's (81): No.	4's (81): %	5's (82): No.	5's (82): %	Total: No.	Total: %	$\bar{x}$ Age
Acc. Trays	8-18-25	S	2,892	8.14	C	36	53.7	28	41.9	3	4.4	0	0	67	100.0	2.51
					E	5	35.7	6	42.9	3	21.4	0	0	14	100.0	2.86
					C+E	41	50.6	34	42.0	6	7.4	0	0	81	100.0	2.57
	8-18-26	M	7,508	9.94	C	188	39.8	229	48.6	53	11.2	2	0.4	472	100.0	2.72
					E	29	35.4	36	43.9	17	20.7	0	0.0	82	100.0	2.85
					C+E	217	39.2	265	47.8	70	12.6	2	0.4	554	100.0	2.74
	8-18-22	L	4,998	12.64	C	228	52.7	143	33.0	62	14.3	0	0	433	100.0	2.62
	8-18-27				E	16	32.0	23	46.0	11	22.0	0	0	50	100.0	2.90
					C+E	244	50.5	166	34.4	73	15.1	0	0	483	100.0	2.65
		T	15,398	9.92	C	452	46.5	400	41.2	118	12.1	2	0.2	972	100.0	2.66
					E	50	34.2	65	44.5	31	21.3	0	0	146	100.0	2.87
					C+E	502	44.9	465	41.6	149	13.3	2	0.2	1,118	100.0	2.69

Table 7 (cont'd)

Treatment	Tag code	Juveniles: Size group	Juveniles: No. tagged	Juveniles: $\bar{x}$ weight (g)	Recovered	2's (79) No.	2's (79) %	3's (80) No.	3's (80) %	4's (81) No.	4's (81) %	5's (82) No.	5's (82) %	Total No.	Total %	$\bar{x}$ Age
Acc.	8-18-28	S	3,995	6.88	C	41	32.3	75	59.0	11	8.7	0	0	127	100.0	2.76
					E	5	33.3	7	46.7	3	20.0	0	0	15	100.0	2.87
					C+E	46	32.4	82	57.7	14	9.9	0	0	142	100.0	2.77
	8-18-29	M	8,539	9.53	C	200	40.2	211	42.4	42	8.4	45	9.0	498	100.0	2.86
					E	28	50.9	14	25.5	13	23.6	0	0	55	100.0	2.73
					C+E	228	41.2	225	40.8	55	9.9	45	8.1	553	100.0	2.85
	8-18-30	L	4,248	10.45	C	109	33.8	182	56.6	31	9.6	0	0	322	100.0	2.76
					E	13	33.3	18	46.2	8	20.5	0	0	39	100.0	2.87
					C+E	122	33.8	200	55.4	39	10.8	0	0	361	100.0	2.77
		T	16,782	8.72	C	350	37.0	468	49.4	84	8.9	45	4.7	947	100.0	2.81
					E	46	42.4	39	35.8	24	22.0	0	0	109	100.0	2.80
					C+E	396	37.5	507	48.0	108	10.2	45	4.3	1,056	100.0	2.81
	Grand Total		32,180	9.30	C	802	41.8	868	45.2	202	10.5	47	2.5	1,919	100.0	2.74
					E	96	37.6	104	40.8	55	21.6	0	0	255	100.0	2.84
					C+E	898	41.3	972	44.7	257	11.8	47	2.2	2,174	100.0	2.75

Table 8. Number of male and female chinooks, and percent males by age of return in escapement to Big Qualicum River, from juvenile releases in 1976, 1977, and 1978.

Release date	Tag code	Juveniles $\bar{x}$ weight (g)	2's			3's			4's			5's			Total		
			No.			No.			No.			No.			No.		
			♂	♀	% ♂	♂	♀	% ♂	♂	♀	% ♂	♂	♀	% ♂	♂	♀	% ♂
June 12/76	8-6-10	3.58	0	0	-	0	0	-	1	1	50.0	0	0	-	1	1	50.0
	8-6-11	5.10	0	0	-	2	1	66.6	9	14	39.1	0	2	0.0	11	17	39.3
	8-6-12	6.59	0	0	-	9	1	90.0	0	2	0.0	0	0	-	9	3	75.0
	Total	5.20	0	0	-	11	2	84.6	10	17	37.0	0	2	0.0	21	21	50.0
Apr 20-26 /77	8-16-6 to 8-16-24	6.90	0	0	-	5	8	38.5	0	0	-	0	0	-	5	8	38.5
June 2-5/78	8-18-25	8.14	5	0	100.0	6	0	100.0	0	3	0.0	0	0	-	11	3	78.6
	8-18-26	9.94	29	0	100.0	18	18	50.0	3	14	17.7	0	0	-	50	32	61.0
	8-18-27	12.64	16	0	100.0	18	5	78.3	2	9	18.2	0	0	-	36	14	72.0
	8-18-22 Total	9.92	50	0	100.0	42	23	64.6	5	26	16.1	0	0	-	97	49	66.4
	8-18-28	6.88	5	0	100.0	7	0	100.0	2	1	66.6	0	0	-	14	1	93.3
	8-18-29	9.53	28	0	100.0	11	3	70.6	2	11	15.4	0	0	-	41	14	74.6
	8-18-30	10.45	13	0	100.0	13	5	72.2	1	7	12.5	0	0	-	27	12	69.2
	Total	8.73	46	0	100.0	31	8	79.5	5	19	26.3	0	0	-	82	27	75.2

Table 9. Number (N) and percent (%) fish caught in different fisheries[a] between 1977 and 1980, from the June 12, 1976 release, by age in year of capture.

		Troll					B.C. Net				Sport		Mixed	Net	U.S.A. Sport	Comm.	
Age		N	C	NW	SW	GS	N	C	JF	JS	C	GS	Net	WA	WA	AL	Total
2	No	0	4	0	0	3	0	19	5	17	0	108	3	0	0	0	159
	%	0	2.5	0	0	1.9	0	11.9	3.1	10.8	0	67.9	1.9	0.0	0.0	0.0	100.0
3	No	3	17	2	0	58	0	12	0	15	7	53	2	0	0	22	191
	%	1.6	8.9	1.1	0.0	30.4	0.0	6.3	0.0	7.7	3.7	27.7	1.1	0.0	0.0	11.5	100.0
4	No	0	8	0	4	3	6	0	0	12	0	20	0	0	0	6	59
	%	0.0	13.6	0.0	6.8	5.1	10.2	0.0	0.0	20.3	0.0	33.8	0.0	0.0	0.0	10.2	100.0
5	No	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	No	3	29	2	4	64	6	31	5	44	7	181	5	0	0	28	409
	%	0.7	7.1	0.5	1.0	15.6	1.5	7.6	1.2	10.8	1.7	44.2	1.2	0.0	0.0	6.9	100.0

[a]Fisheries are:

Full name	Statistical areas
N - Northern troll	1-5
C - Central troll	6-12, 30
NW - Northwest troll	25-27
SW - Southwest troll	21, 23 & 24
GS - Georgia Strait troll	13-18, 29A, B, & C
N - Northern net	1-5
C - Central net	6-11
JF - Juan de Fuca net	20
JS - Johnstone Strait net	12-13
C - Central Sport	6-12
GS - Georgia Strait sport	13-20, 28, 29A, B, & C
WA - Washington State	
AL - Alaska	

Table 10. Number (No) and percent (%) fish caught in different fisheries[a] between 1978 and 1981, from April 20-26, 1977 release, by age in year of capture.

Age		Troll		Net	Sport	Total
		N	GS	JS	GS	
2	No	0	3	6	27	36
	%	0	8.3	16.7	75.0	100.0
3	No	0	10	0	20	30
	%	0	33.3	0	66.7	100.0
4	No	5	0	2	0	7
	%	71.4	0	28.6	0	100.0
5	No	0	0	0	0	0
	%	0.0	0.0	0.0	0.0	0.0
Total	No	5	13	8	47	73
	%	6.9	17.8	10.9	64.4	100.0

[a]Fisheries are:

Full name	Statistical Areas
N - Northern troll	1-5
GS - Georgia Strait troll	13-18, 29A, B, & C
JS - Johnstone Strait net	12-13
GS - Georgia Strait sport	13-20, 28, 29A, B, & C

Table 11. Number (N) and percent (%) fish caught in different fisheries[a] between 1979 and 1982, from the June 2-5, 1978 release, by age in year of capture.

			B.C.												U.S.A.				
			Troll					Net			Sport			Mixed		Net	Sport	Comm.	
Treatment	Age		N	C	NW	SW	GS	N	C	JS	GS	C	NC	Troll	Net	WA	WA	AL	Total
Accel Trays	2	No	0	0	0	0	46	18	27	52	309	0	0	0	0	0	0	0	452
		%	0	0	0	0	10.2	4.0	6.0	11.5	68.3	0	0	0	0	0	0	0	100.0
	3	No	40	42	5	12	101	11	5	40	128	7	0	0	2[a]	1[a]	1[a]	5	400
		%	10.0	10.5	1.3	3.0	25.3	2.8	1.3	10.0	32.0	1.8	0	0	0.5	0.3	0.3	1.3	100.0
	4	No	8	35	13	0	3	6	4	2	41	0	0	0	0	0	0	6	118
		%	6.8	29.7	11.0	0	2.5	5.1	3.4	1.7	34.7	0	0	0	0	0	0	5.1	100.0
	5	No	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
		%	0	100.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100.0
	Total	No	48	79	18	12	150	35	36	94	478	7	0	0	2[a]	1	1	11	972
		%	4.9	8.1	1.9	1.2	15.4	3.6	3.7	9.7	49.3	0.7	0	0	0.2	0.1	0.1	1.1	100.0
Accel gravel	2	No	0	0	0	0	38	9	59	23	221	0	0	0	0	0	0	0	350
		%	0	0	0	0	10.9	2.6	16.8	6.6	63.1	0	0	0	0	0	0	0	100.0
	3	No	22	38	0	0	140	34	10	30	174	14	0	1[a]	0	1[a]	0	4	468
		%	4.7	8.1	0	0	29.9	7.3	2.1	6.4	37.2	3.0	0	0.2	0	0.2	0	0.9	100.0
	4	No	8	11	0	0	19	2	0	10	21	0	7	0	0	0	0	6	84
		%	9.5	13.1	0	0	22.7	2.4	0	11.9	25.0	0	8.3	0	0	0	0	7.1	100.0
	5	No	9	29	0	0	7	0	0	0	0	0	0	0	0	0	0	0	45
		%	20.0	64.4	0	0	15.6	0	0	0	0	0	0	0	0	0	0	0	100.0
	Total	No	39	78	0	0	204	45	69	63	46	14	7	1[a]	0	1	0	10	947
		%	4.1	8.2	0	0	21.5	4.8	7.3	6.7	43.9	1.5	0.7	0.1	0	0.1	0	1.1	100.0

Table 11 (cont'd)

			B.C.													U.S.A.			
			Troll					Net			Sport			Mixed		Net	Sport	Comm.	
Treatment	Age		N	C	NW	SW	GS	N	C	JS	GS	C	NC	Troll	Net	WA	WA	AL	Total
Trays &	2	Nb	0	0	0	0	84	27	86	75	530	0	0	0	0	0	0	0	802
Gravel		%	0	0	0	0	10.5	3.4	10.7	9.3	66.1	0	0	0	0	0	0	0	100.0
	3	Nb	62	80	5	12	241	45	15	70	302	21	0	1*	2	2*	1*	9	868
		%	7.1	9.2	0.6	1.4	27.9	5.2	1.7	8.1	34.8	2.4	0	0.1	0.2	0.2	0.1	1.0	100.0
	4	Nb	16	46	13	0	22	8	4	12	62	0	7	0	0	0	0	12	202
		%	7.9	22.8	6.4	0	10.9	4.0	2.0	5.9	30.7	0	3.5	0	0	0	0	5.9	100.0
	5	Nb	9	31	0	0	7	0	0	0	0	0	0	0	0	0	0	0	47
		%	19.2	66.0	0	0	14.8	0	0	0	0	0	0	0	0	0	0	0	100.0
	Total	Nb	87	157	18	12	354	80	105	157	894	21	7	1*	2*	2	1	21	1,919
		%	4.5	8.2	0.9	0.6	18.5	4.2	5.5	8.2	46.6	1.1	0.4	<0.1	0.1	0.1	<0.1	1.1	100.0

Fisheries are:

Full Name	Statistical Areas
N - Northern troll	1-5
C - Central troll	6-12, 30
NW - Northwest troll	25-27
SW - Southwest troll	21, 23 & 24
GS - Georgia Strait troll	13-18, 29A, B, & C
N - Northern net	1-5
C - Central net	6-11
JS - Johnstone Strait net	12-13
GS - Georgia Strait sport	13-20, 28, 29A, B, & C
C - Central sport	6-12
NC - West Coast Vancouver I. sport	21-27
WA - Washington State	
AL - Alaska	

*Observed recoveries

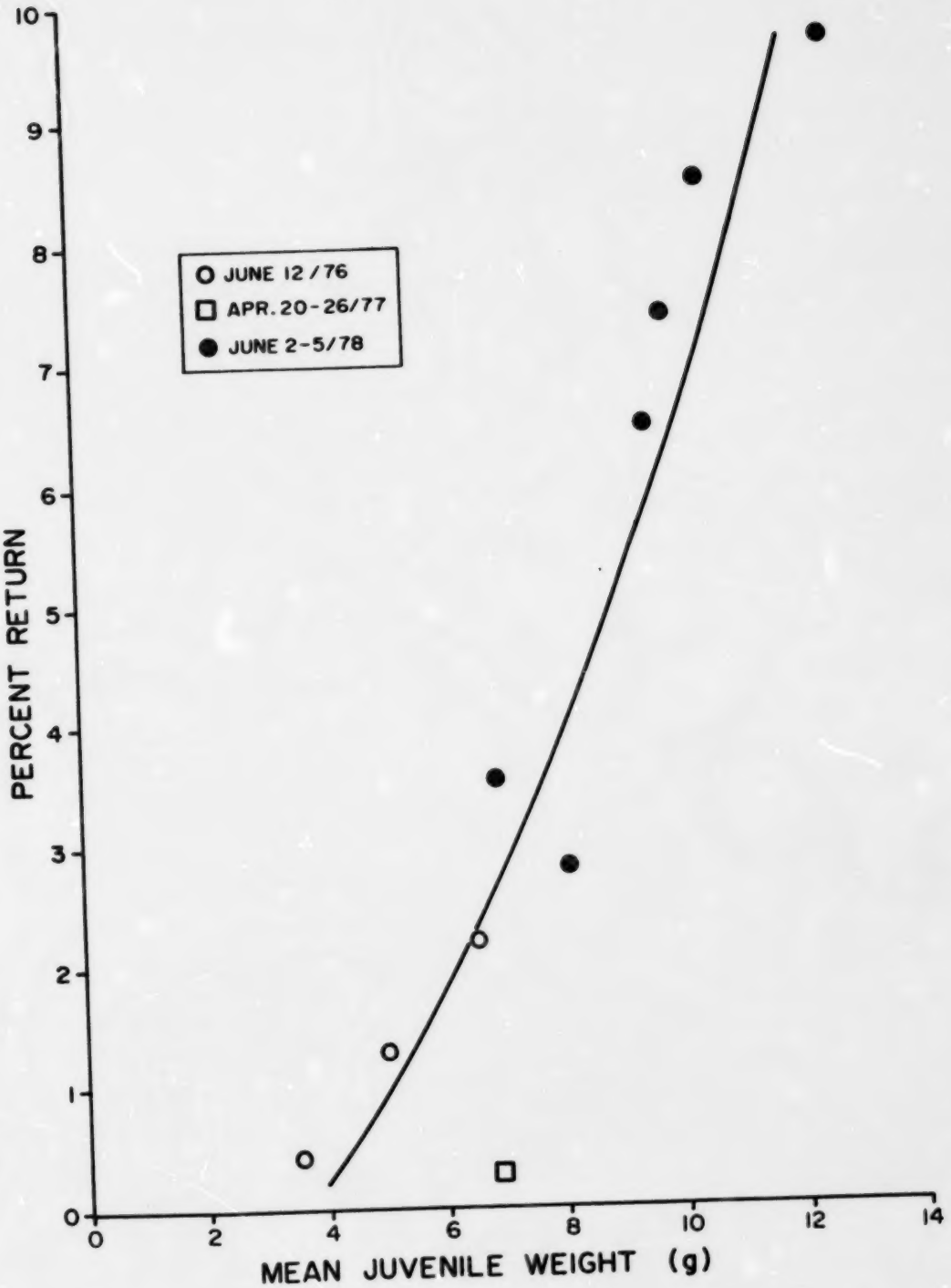

Fig. 1. Compares the percent return (catch + escapement) of chinooks, all ages combined, originating from juvenile of different sizes released in 1976, 1977, and 1978.

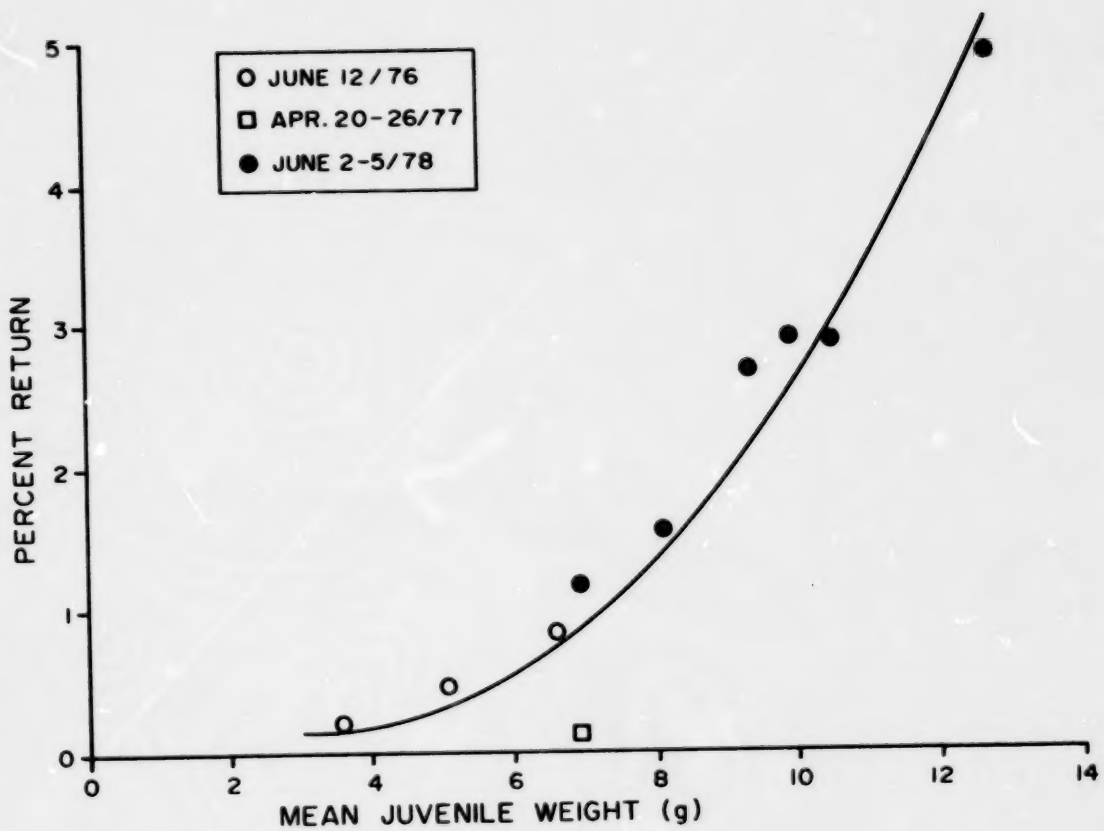

Fig. 2. Compares the percent return (catch + escapement) of 2-year-old chinooks, originating from juveniles of different sizes released in 1976, 1977, and 1978.

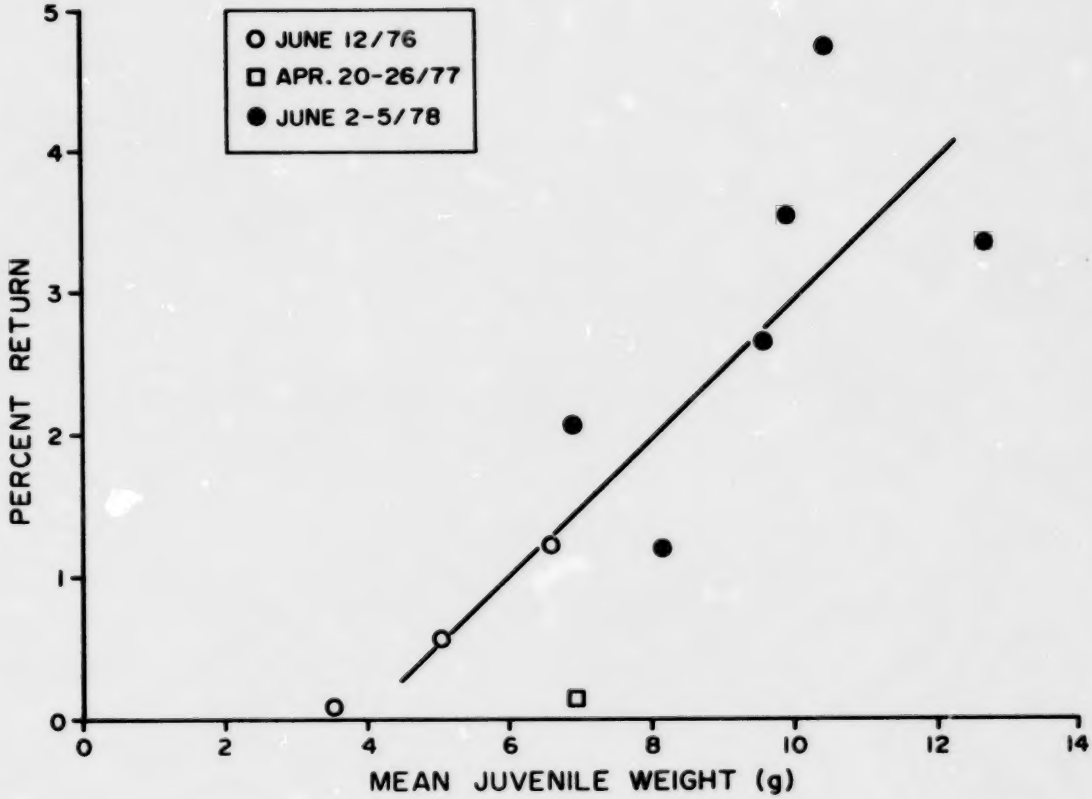

Fig. 3. Compares the percent return (catch + escapement) of 3-yrear-old chinooks, originating from juveniles of different sizes released in 1976, 1977, and 1978.

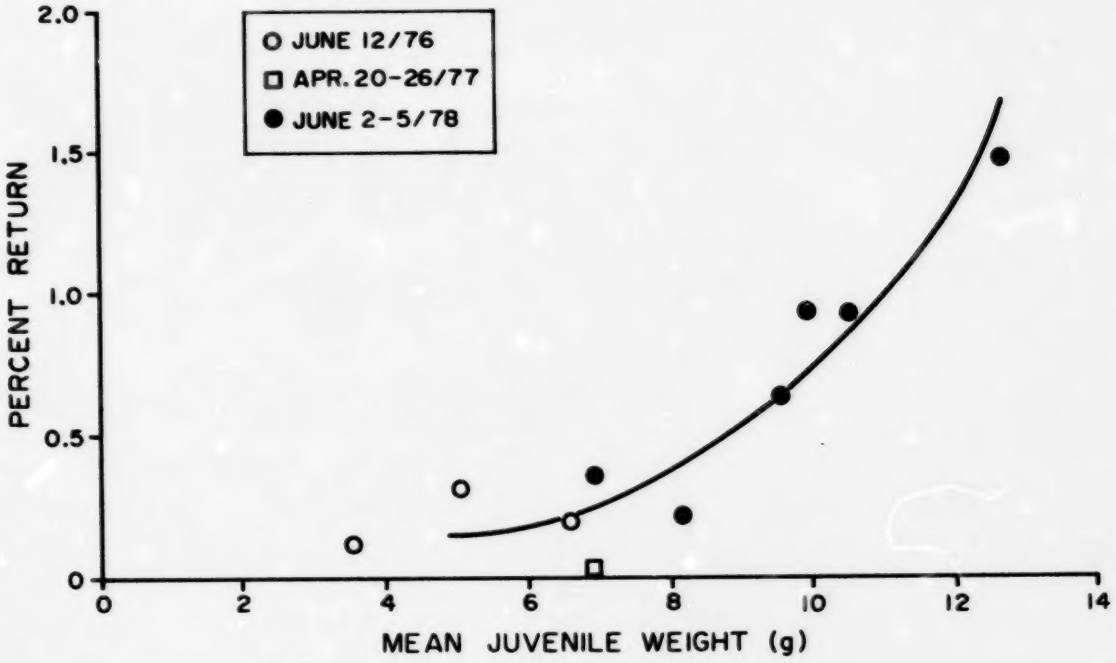

Fig. 4. Compares the percent return (catch + escapement) of 4-year-old chinooks, originating from juveniles of different sizes released in 1976, 1977, and 1978.

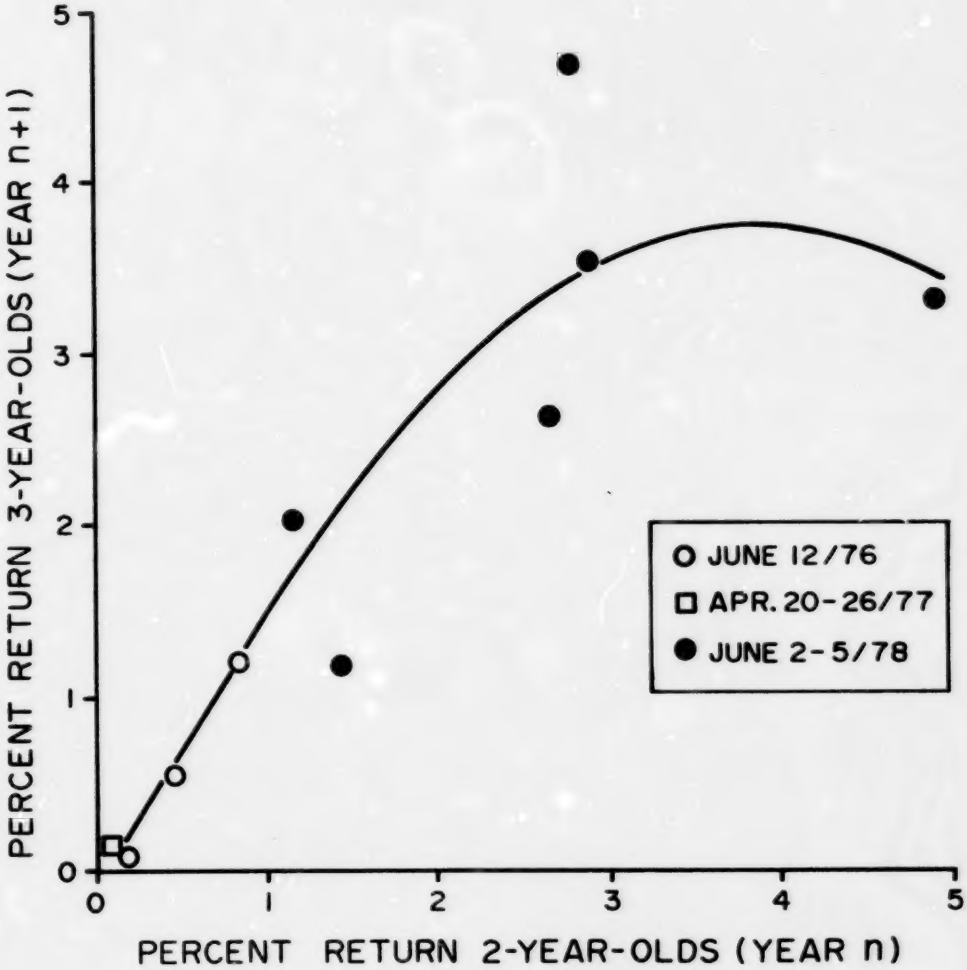

Fig. 5. Compares the percent of juveniles that returned as 2-year-olds in year n with the percent juveniles that returned as 3-year-olds in year n + 1 (catch + escapement).

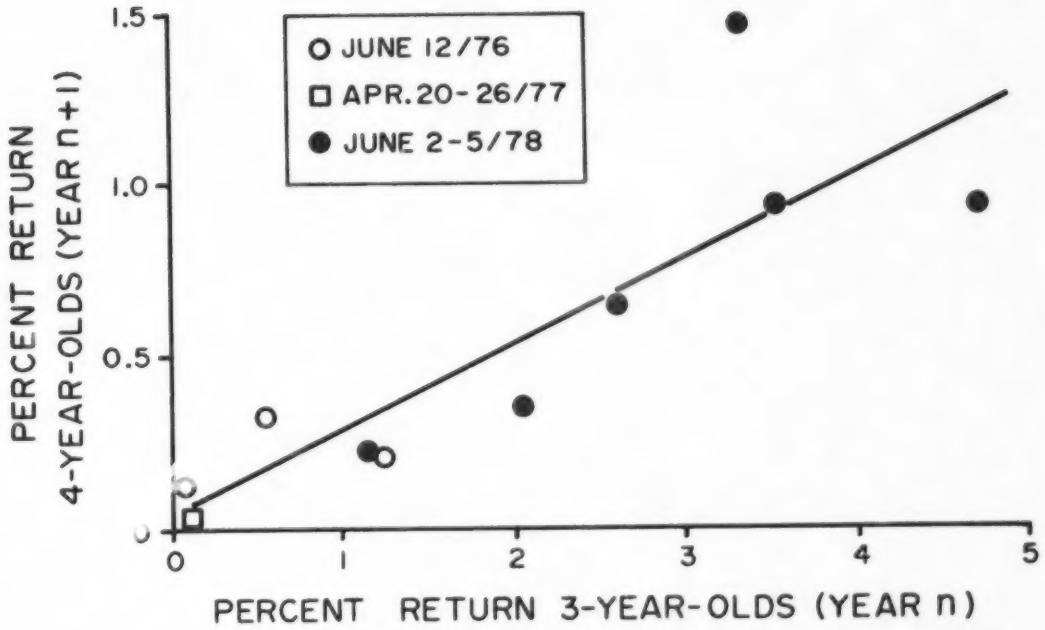

Fig. 6. Compares the percent of juveniles that returned as 3-year-olds in year n with the percent juveniles that returned as 4-year-olds in year n + 1 (catch + escapement).

POOR

QUALITY

ORIGINAL